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SIGNAL FLUCTUATIONS IN THE BIFI RANGE.(U)
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NAVAL UNDERWATER SYSTEMS CENTER

9 Technical Memo

6 SIGNAL FLUCTUATIONS IN THE BIFI RANGE.

11 Date: 27 Oct 71

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[1] This memorandum consists of the abstract, text and slides of a paper presented at the Eighty-Second Meeting of the Acoustical Society of America in Denver, Colorado on 20 October 1971.

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ABSTRACT[2]

Short-term and long-term fluctuation studies have been made in the BIFI Shallow Water Acoustic Range, which is 37 kiloyards in length. It is shown how time smear analysis may be used to predict the extent of short-term signal fluctuation by taking into account the energy content of the "front" and "tail" of the received signal. The method is applied to an actual received signal with good results. Long-term fluctuation, such as that due to tide, is considered in terms of normal mode theory, using the results of the time smear analysis to provide an estimate of the relative strengths of the modes. When applied to the BIFI range this method predicts that tidal effects will cause negligible fluctuations in the received signal, due to the absence of modes other than the fundamental at this large range. This prediction was verified by experiment. At shorter ranges, the interaction of several modes will cause relatively large fluctuations in the signal as the water depth changes during the tidal cycle.

[2]This abstract was previously published in The Program of the Eighty-Second Meeting of the Acoustical Society of America, Denver, Colorado 19-22 October 1971.

ADMINISTRATIVE INFORMATION

This memorandum was prepared under Project No. A-650-09, Sub-Project No. SF 11 552 008-14054, "(U) Shallow Water Acoustic Theory and Measurements For Sonar Systems Design and Operation," Principal Investigators W. R. Schumacher / B. Sussman, Code TA11. The sponsoring activity is Naval Ship Systems Command 901L, Program Manager J. Reeves.

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TEXT

The Naval Underwater Systems Center is engaged in a series of acoustic propagation investigations for the purpose of formulating an accurate model suitable for sonar performance prediction in shallow water. Among the phenomena being investigated are short-term and long-term signal fluctuations. The present paper (reference (1)) is an extension of a previous one devoted partly to this subject, and discusses the use of normal mode theory in accounting for observed fluctuations.

The tests discussed here were conducted on the BIFI range shown in Figure 1. The range has a length of approximately 19 nautical miles and a depth of about 110 feet through most of its extent. At Block Island, a projector with an operating frequency of 1700 Hertz is bottom mounted at a 55-foot depth. Several receiving hydrophones are bottom mounted near Fishers Island. The one currently being used is located in 155 feet of water.

Fluctuation studies have been conducted on the BIFI range and results obtained from these tests have been reported previously at the 78th Meeting of the Society (November 1969). However (reference (1)) these tests were of relatively short duration. The present paper describes a series of tests which were scheduled to be conducted for 48 consecutive hours. This allowed the study of both short and long term fluctuation effects. All tests were conducted when winter conditions prevailed and the water column was approximately isothermal. Hence fluctuations were measured when internal wave motion was at a minimum.

Time smear analysis of short pulses has been used to study short term fluctuations. A review of the method is provided in Figure 2. Briefly, the outgoing pulse is assumed to be rectangular, of duration T_o. That part of the received signal which contains the maximum energy in an interval T_o is called the "main pulse." The "front" and "tail" are the portions of the signal adjacent to the main pulse whose energy content and acoustic pressure are above a predetermined threshold with respect to the ambient noise.

The results of the time smear analysis of a series of pulses may be used to predict signal fluctuations in C.W. signals. Variations in signal level can be attributed to two factors. First, there is the variation in the energy of the main pulse in a series of received signals. This can cause a maximum variation in the envelope equal to the ratio of the energy in the largest main arrival to that of the smallest main arrival and is given by Δ_1 . Second, is the effect due to interference between the main pulse and other arrivals. The maximum due to this effect is given by Δ_2 . Since these effects may reasonably be assumed to be independent, the total maximum variation would be the sum of the two components.

As one application of this method, the median value of Δ_2, the component of signal variation due to multipath, was found for each of four tests, and tabulated, together with the prevailing sea states, in Figure 3. It can be seen that, for all sea states considered, the median fraction of energy in the tail, F(tail), is relatively small. This indicates that the first arrival, i.e. the first mode, dominates the sound field and that relatively little energy is contained in higher order modes. The resulting values of Δ_2 were only about 5 dB at all sea states. It may be noted that Δ_2 does increase slowly with sea state.

The duration of the test in January 1968 was 48 hours. Every 30 minutes during this test the sequence of signals shown in Figure 4 was received. About ten 45-second pulses were followed by 8 pulses 250 milliseconds in length. The median values of Δ_2 computed from each sequence of short pulses are shown in Figure 5. The spread of the data about the 5 dB median value is extremely small. By contrast there is rapid fluctuation in the magnitude of fading in the long pulses. Shown in Figure 6 is the maximum signal variation in dB in the last long pulse in each sequence over the 48-hour period. The magnitude of the fading varied from 6 to 43 dB. The median value is in excess of 20 dB. Analysis of the short pulses indicates that about 12 dB of this median value can be attributed to variation of the main pulse and about 8 dB to the interference effect due to multipath. Thus it appears that, even in the absence of internal waves and with relatively little multipath strength, large and irregular fading can occur.

We now turn to consideration of fluctuations caused by tidal changes. A change in water depth may affect acoustic transmission in two ways: (1) It may alter the energy distribution in the water column; and (2) It may alter the phase relationship between the modes which make up the sound field. For the low order modes considered in this paper the second effect is much more important than the first.

Calculations of the effect of tide were made using normal mode theory. The following assumptions were made: (1) Values obtained as a result of extensive measurements were used for parameters of the BIFI range; (2) The maximum depth change due to tide, as taken from tide tables for the area, was three feet; (3) The frequency was taken at 1700 Hertz, the same frequency as used in the long term experiments; (4) The received signal was assumed to consist of the first two modes, with 10% of the total energy in the second mode. This was based on the results given in Figure 3 which showed about 6% to 8% of the energy in higher modes. Concentrating all of this energy in the second mode constitutes a kind of "worst case."

A plot of the results of the calculations is shown in Figure 7. The curve of signal level versus water depth has the appearance of an incomplete sinusoid. The maximum change in signal level due to the tide is only 2.7 dB. In the actual case, this change may be expected to be smaller than shown, for two reasons. First, the higher order energy may be distributed in several modes, rather than only the second mode. Second, for calculations purposes it was assumed that the relative phase between the two modes is fixed and does not vary with time, while in fact the relative phase is likely to be somewhat incoherent. Both these randomizing effects would tend to reduce the change in level caused by tide and it is to be expected that this tidal effect would be lost in the much larger short term fluctuations and changes due to other environmental factors.

Figure 8 is an illustration of this. It shows values of signal level and wind speed as a function of time for 30 hours as observed in tests conducted in January 1968. In the first 12 hours, as the wind speed increased from 5 to 20 miles per hour, the signal level decreased by 20 dB, (from 35 to 15). Also, short term fluctuations of the order of 20 dB are evident. Thus the tidal effect is lost in these large changes. Spectra of the data were obtained of wind speed and signal level. No pronounced periods were noted in any of these curves.

We have discussed the effect of tide in one specific case. A consideration of the theoretical effect in other cases illustrates certain interesting tidal effects. In Figure 9 are shown two plots of signal level versus water depth. The assumptions are the same as in the previous case except that the sound field is composed of two modes of equal amplitude. The range for which the curve on the right is calculated is 2000' greater than that of the left curve. Three effects are apparent: (1) As before the curves are in the form of an incomplete sinusoid. However, there is in effect a time lag betwen the tidal effect at different ranges; (2) Due to this time lag different portions of the sinusoid are traced over the tidal cycle. The curve on the right follows the shallow part of the sinusoid and the maximum amplitude difference is only 4.6 dB. At a range only 2000' away the resulting signal variation is 23.2 dB since the curve follows the steep part of the sinusoid; and (3) Finally, it is noted that the basic order of magnitude of signal variation when two modes of equal amplitude compose the sound field far exceeds that when one mode dominates the sound field.

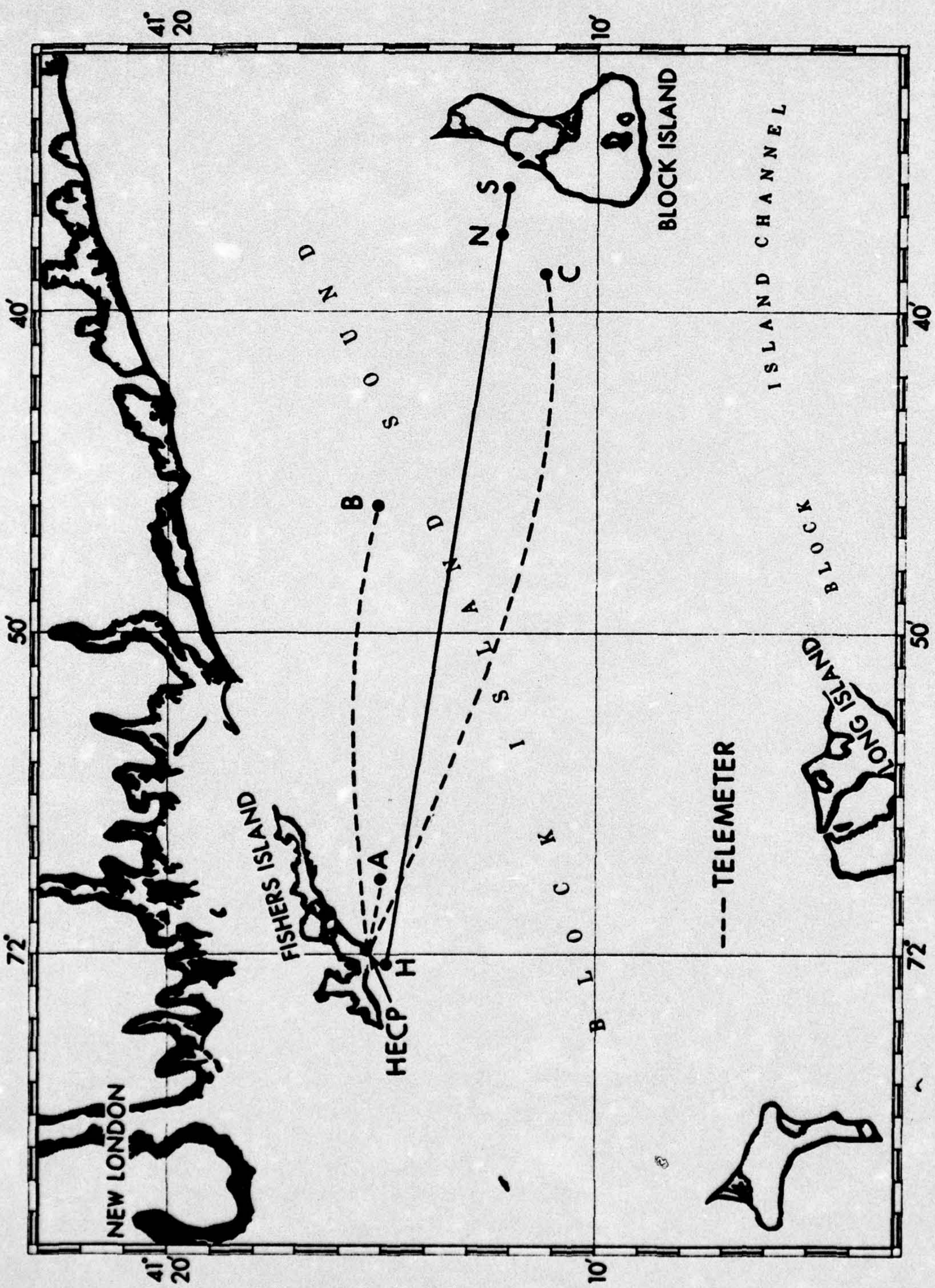
In Figure 10 are shown two plots of signal level versus water depth. The assumptions are the same as in the previous cases except that the sound field is composed of four modes each of which suffers the same bottom loss. The source depth corresponding to the left curve is 55 feet while that corresponding to the right curve is 105 feet. Two effects are apparent: (1) The amplitude fluctuates more rapidly than in the previous case. This occurs because of the large path difference between the first mode and the higher order modes introduced; (2) The magnitude of the signal variation is highly dependent upon source depth since the relative strength of the modes is a function of depth. The maximum signal variation increases from 5.2 to 13.2 dB when the source depth is changed from 55 to 105 feet. The same effect can be achieved by varying the receiver depth.

Finally it must be noted that nearly all of the previously mentioned parameters are a function of frequency. Frequency must be taken into account in any calculation.

To summarize, it has been shown how normal mode theory has been used to predict signal fluctuations at long ranges. A method of predicting short term fluctuations was described. Fluctuations due to tide were also discussed, and it was concluded that because of the long ranges involved in the BIFI tests, these fluctuations were expected to be negligible.

REFERENCES

1. B. Sussman and W. G. Kanabis, "Time Smear and Frequency Smear Studies on the BIFI Range," NUSL Tech Memo No. 2211-11-70, 20 January 1970.



BIFI RANGE

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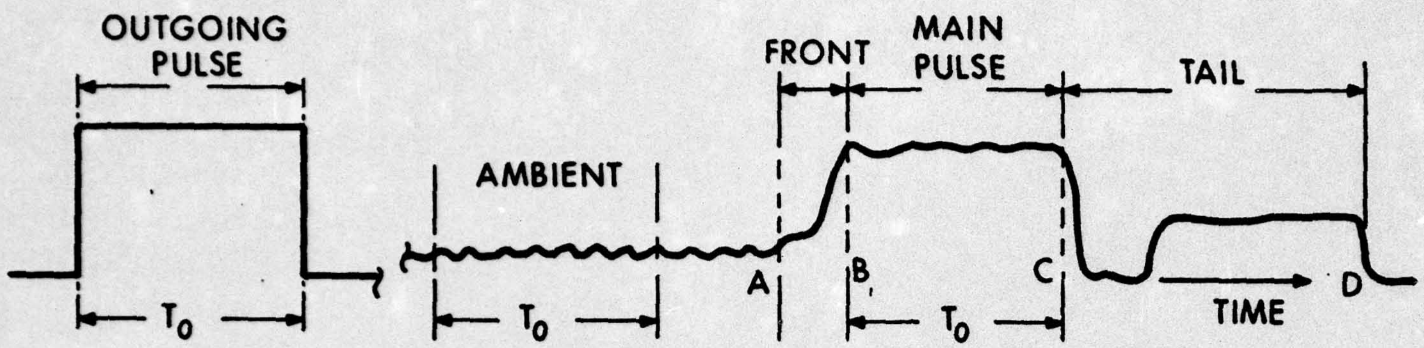
Figure 1



REPRESENTATION OF OUTGOING AND RECEIVED PULSE

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Figure 2

DATE	DURATION (HOURS)	SEA STATE	MEDIAN F (TAIL)	Δ_2 (dB)
FEB 1969	1	0-1	.066	4.5
APRIL 1968	36	0-1	.068	4.6
JAN 1968	48	1-2	.078	5.0
DEC 1967	2	2-3	.081	5.2

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Figure 3

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SEQUENCE OF RECEIVED SIGNALS

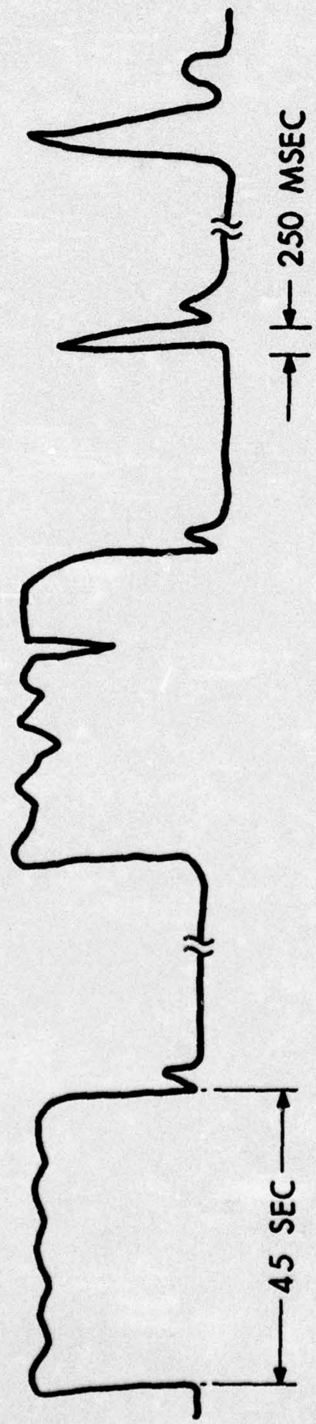

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Figure 4

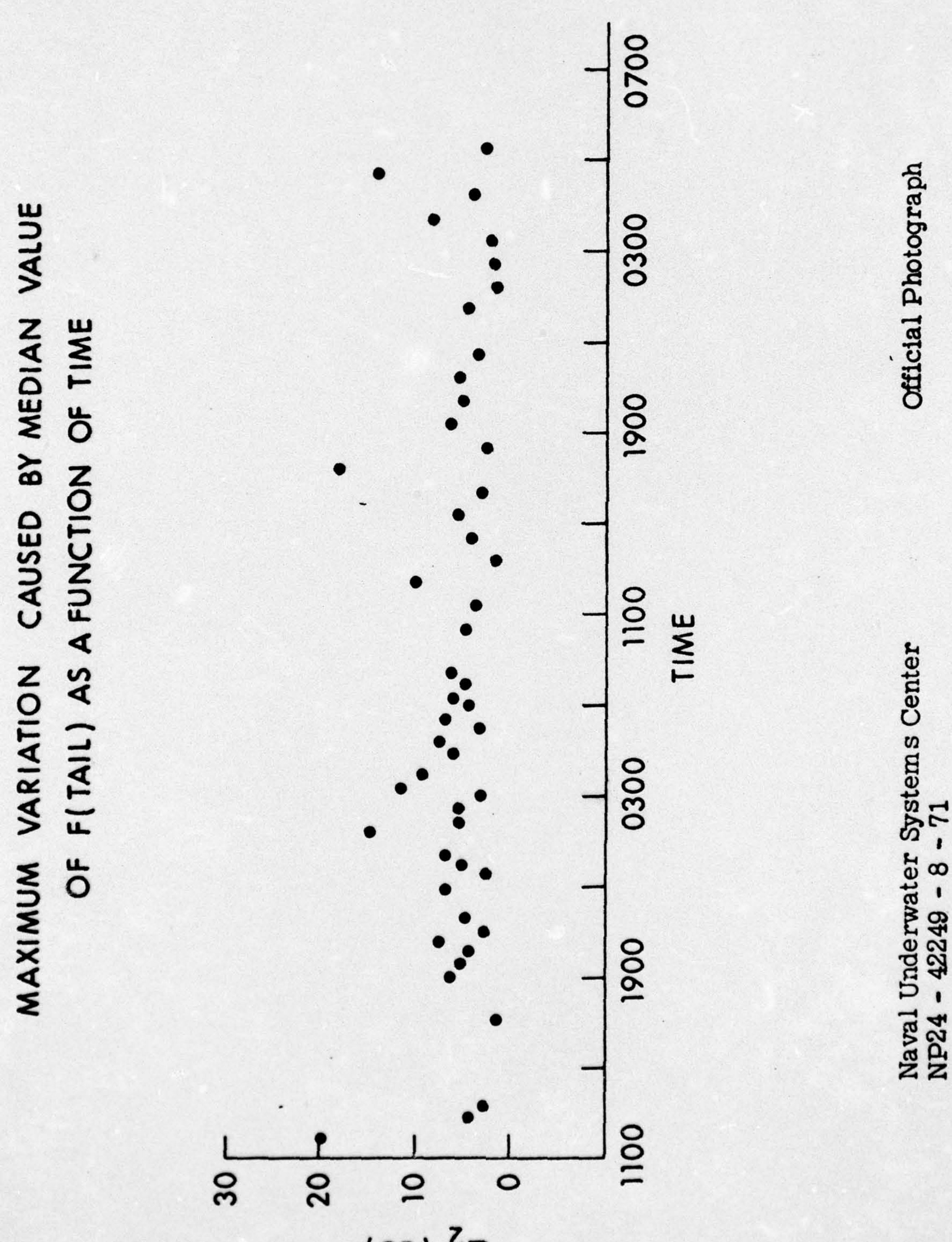
MAXIMUM VARIATION CAUSED BY MEDIAN VALUE
OF F(TAIL) AS A FUNCTION OF TIME
Δ_2 (dB)
30
20
10
0
1100
1900
0300
1100
1900
0300
0700
TIME
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Figure 5

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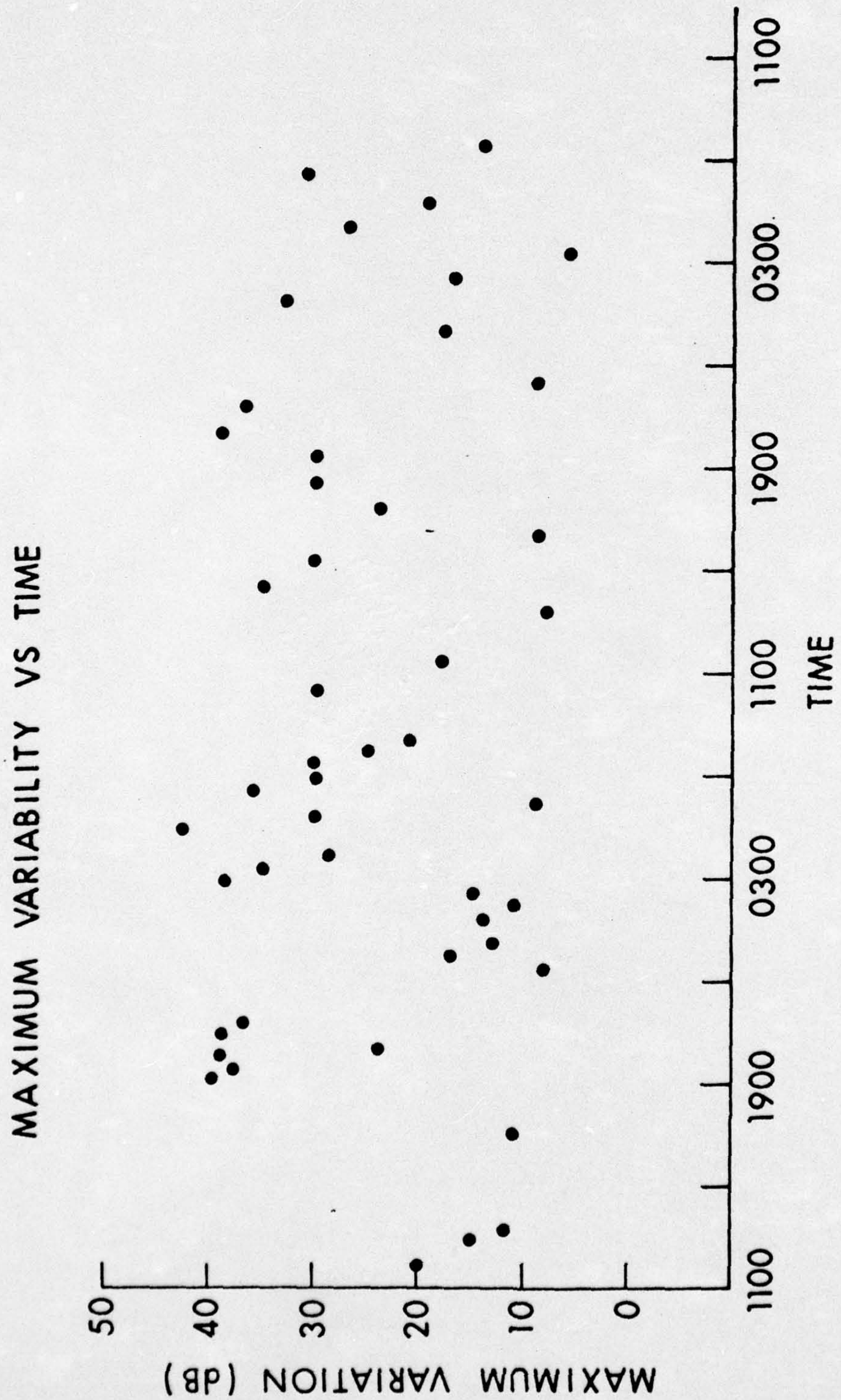

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Figure 6

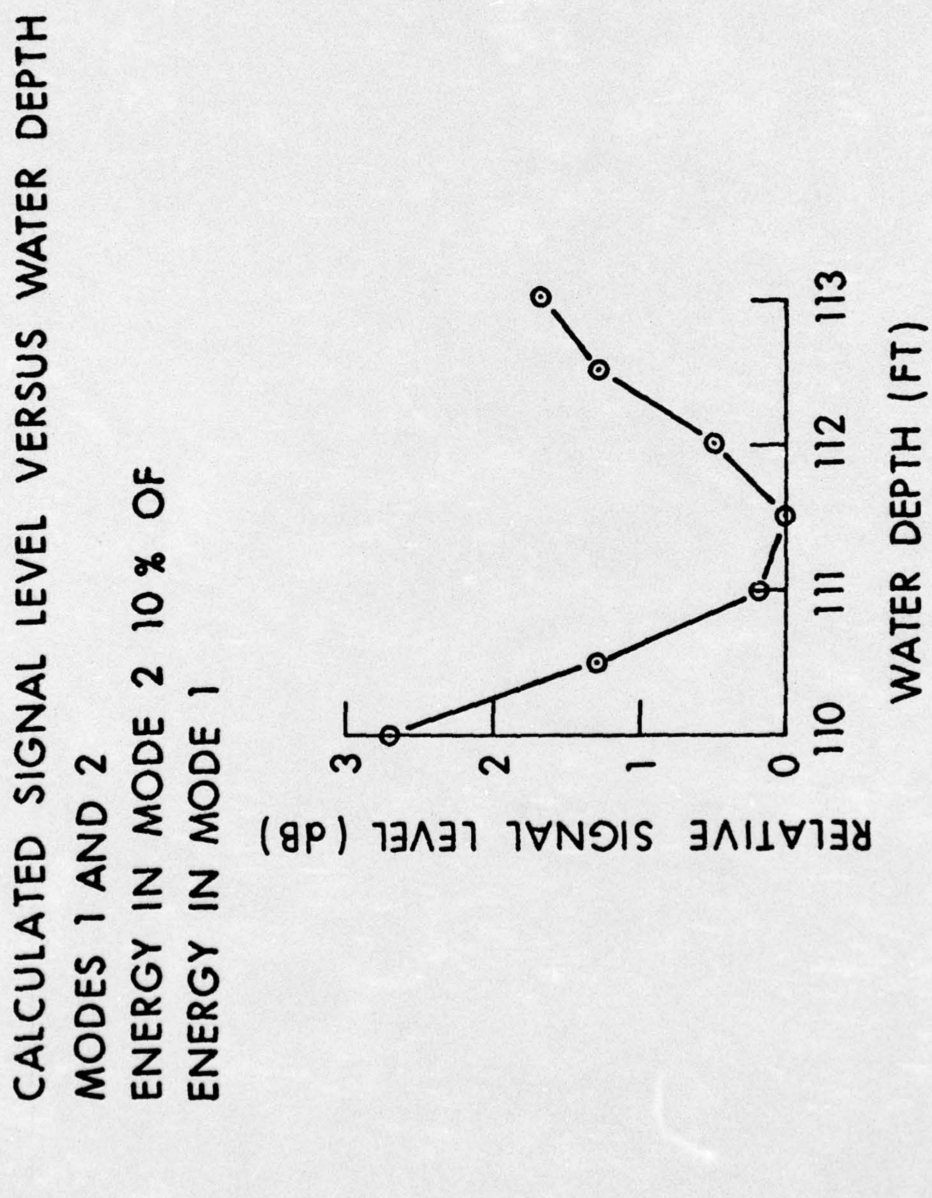

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Figure 7

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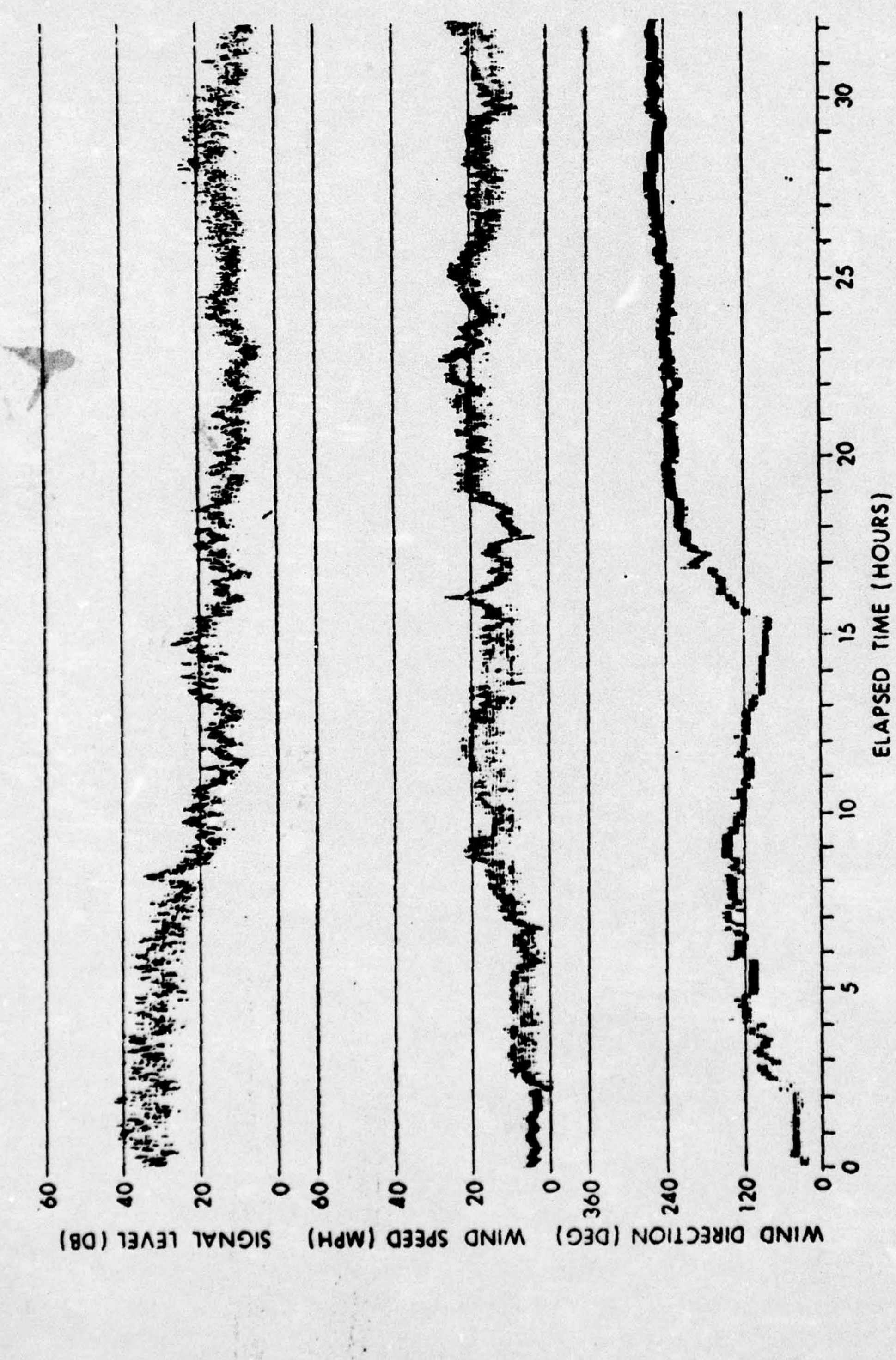

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Figure 8

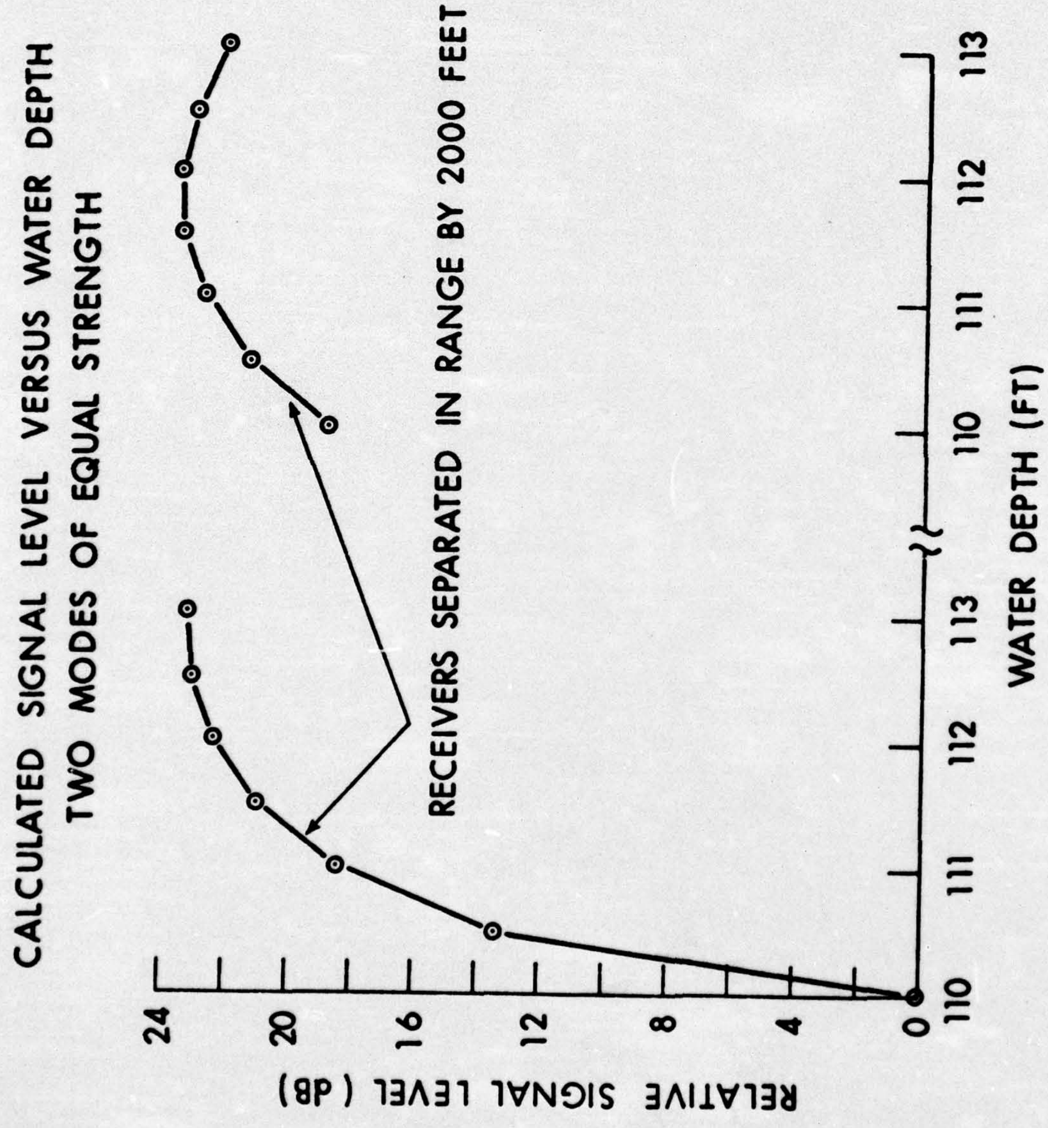

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Figure 9

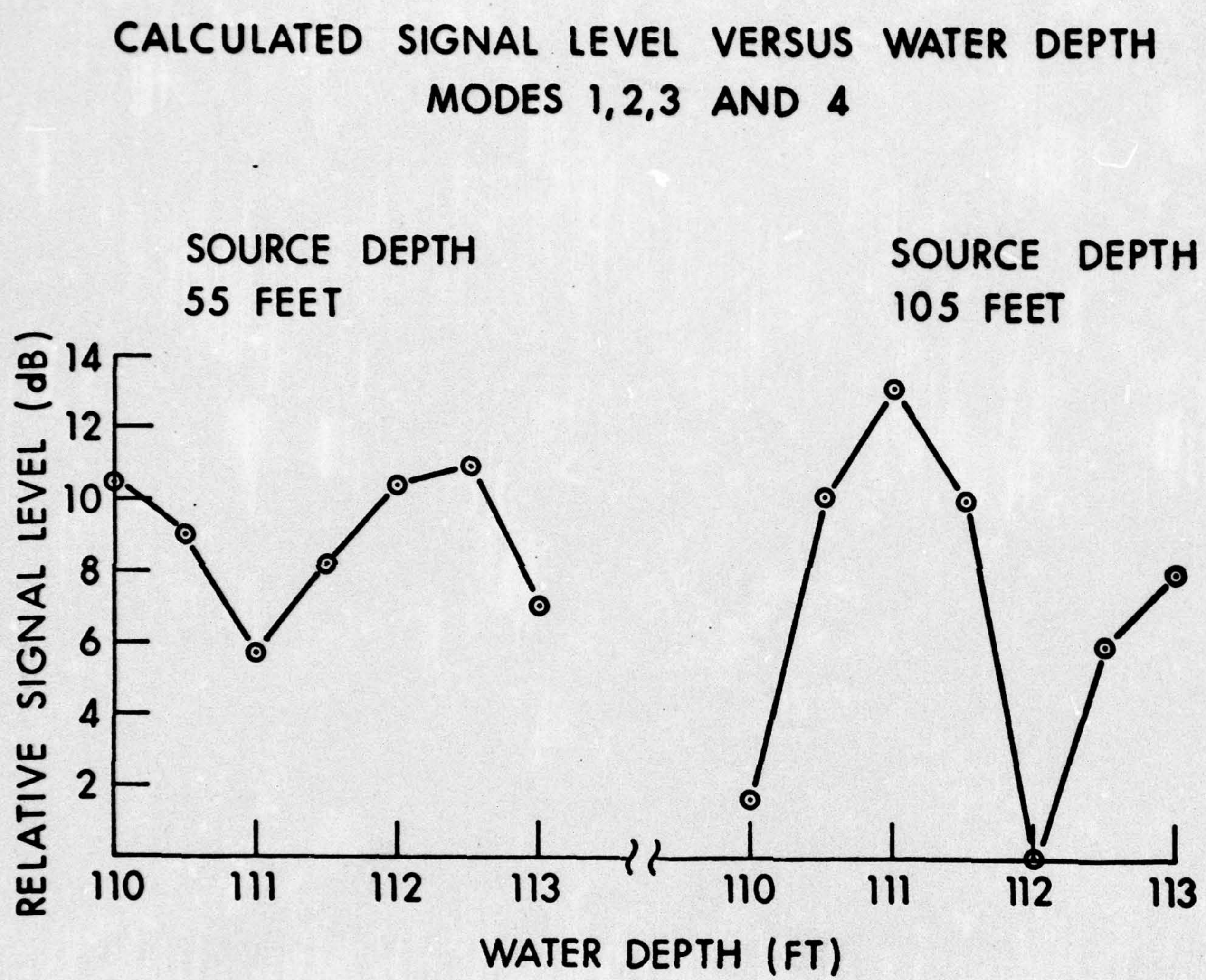

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Figure 10